COMBINED USE TIMER SYSTEM FOR DATA COMMUNICATION

Technical Field

[0001] This invention relates to telecommunication equipment. The invention has application in asynchronous transfer mode (ATM) devices. The invention relates specifically to combined use timers which may be used in combining data into the cells of an ATM connection.

Background

[0002] An ATM connection transmits fixed-length data cells over a physical data link. The physical data link typically comprises a fiber optic cable or an electrical cable. The ATM link is typically divided up into a number of virtual connections. In various situations it is desirable to combine data belonging to one or more channels into one ATM virtual connection which has sufficient bandwidth to service all of the channels. The ATM link is a step in carrying the stream of data from a source to an ultimate destination.

[0003] Within each ATM virtual connection data is carried as a payload in ATM cells. In general, the data in each channel may arrive in packets which are not the same size as the data payload of an ATM cell and may not be an even multiple of the size of the ATM cell data payload. Further, in some cases, packets of data may arrive for transmission across an ATM link in a bursty manner. To conserve bandwidth in the ATM link, some protocols permit delaying the transmission of a partially filled ATM cell until more data arrives from which the partially filled cell can be filled and then sent.

[0004] In many applications it is necessary to keep the latency (i.e. the time taken for each part of a data stream to be transmitted to its destination) within some upper bound. For example, to achieve good

voice quality in a system carrying voice data across a network, delay across the network must be minimal.

[0005] The international telecommunications union (ITU-T) standard I.363.2 provides mechanisms to enforce an upper bound to the time within which any unfilled ATM cells should be dispatched across an ATM link, even if the cells are not yet filled with data. This standard relates to combining multiple ATM adaptation layer 2 (AAL2) coded packets into the cells of a single ATM connection. The packets being combined together may be multiplexed from multiple channels. The standard provides that each AAL2 coded ATM connection shall be equipped with a combined use (CU) timer which measures the delay interval starting at the time that the first data is placed in an ATM cell. A controller monitors the CU timer for each connection and causes any partially filled cell to be sent after a maximum predetermined delay has been reached. Cells which become completely filled before the maximum predetermined delay has been reached are sent without waiting for the maximum predetermined delay to elapse.

[0006] Since a separate timer is typically required for each connection, the number of timers required may be very large. For example, a channelized OC-3 interface might contain up to 2016 channels. If 10 channels are used for each AAL2 connection then there could be a need for as many as approximately 200 CU timers. Implementing such a large number of CU timers in a cost efficient and practical manner presents a significant problem. In some cases even more CU timers will be required.

[0007] There is a need for a way to efficiently and cost-effectively implement CU timers in apparatus for transmitting ATM cells according to standards such as ITU I.363.2. There is a particular need for such

apparatus and methods which can be effectively used in cases where many CU timers are required.

Summary of the Invention

[0008] This invention relates to combined use timer systems and methods. One aspect of the invention provides a method for controlling the dispatch of data to a plurality of destinations on a telecommunication network. The method comprises: receiving a plurality of data streams at an interface on the telecommunication network; accumulating data destined for each of the plurality of destinations; upon the accumulation of a threshold amount of data destined for one of the destinations, dispatching the accumulated data; if there is no accumulated data for a destination then upon the receipt of data destined for that destination which is not dispatched immediately, scheduling an expiry time for the destination and associating the destination with the expiry time; and, when the expiry time occurs, using the association to identify a group of one or more destinations associated with the expiry time and, for the destinations in the group, sending the accumulated data.

[0009] Associating the destination with the expiry time may comprise placing information identifying the destination in a list associated with the expiry time. In some embodiments the list comprises a linked list. In some embodiments the linked list comprises a doubly linked list.

[0010] Another aspect of the invention provides a method for controlling the transmission of fixed-sized data cells on a telecommunication link. The method comprises: receiving a plurality of data streams at an interface to the telecommunication link; assigning data from the data streams into fixed-size cells for transmission across connections in the telecommunication link; upon the creation of a

partially-filled cell to be transmitted on a connection, scheduling an expiry time for the partially-filled cell and associating the connection with the expiry time; and, when the expiry time occurs, using the association to identify a group of one or more connections for which there are partially-filled cells all associated with the expiry time and dispatching the partially-filled cells in the group.

[0011] In some embodiments of the invention the telecommunication link comprises an ATM virtual channel connection and the fixed-size cells comprise ATM cells.

[0012] Yet another aspect of the invention provides apparatus for forwarding data packets over a telecommunication link. The apparatus comprises a plurality of interfaces, each interface receiving one or more streams of data and places the received data into data packets for transmission across a telecommunications link. The apparatus comprises a outgoing cell assembler connected to place data packets onto the telecommunications link and a combined use timer connected to control the transmission of partially-filled data packets over the telecommunications link. Each of the interfaces is configured to provide a partial packet ready signal to the combined use timer upon the creation of a partially-filled data packet containing less than a threshold amount of data. The combined use timer comprises a timer maintaining a current time value, a calculator connected to determine an expiry time for a partially-filled packet corresponding to a partial packet ready signal, a data structure capable of holding information identifying groups of partially-filled packets which share a common expiry time and comparison logic connected to signal to the outgoing cell assembler when the expiry time for a group of one or more partially-filled packets which share a common expiry time has occurred.

[0013] Further features and aspects of the invention are described below.

Brief Description of the Drawings

[0014] In drawings which illustrate non-limiting embodiments of the invention:

Figure 1 is a schematic diagram of an ATM cell transmitting interface according to one of many possible embodiments of the invention;

Figure 2 is a block diagram of a possible embodiment of a combined use timer system;

Figure 3 is a diagram showing a data structure which could be used to track information regarding a connection;

Figure 4 is a diagram illustrating a way to associate connections to expiry times using an expiry time list;

Figure 5 is a diagram illustrating an ATM cell transmitting interface according to another embodiment of the invention;

Figure 6 is a flow chart illustrating a method according to the invention; and,

Figure 7 is a diagram illustrating an interface for transmitting variable-size packets according to the invention.

Description

[0015] Throughout the following description, specific details are set forth in order to provide a more thorough understanding of the invention. However, the invention may be practiced without these particulars. In other instances, well known elements have not been shown or described in detail to avoid unnecessarily obscuring the invention. Accordingly, the specification and drawings are to be regarded in an illustrative, rather than a restrictive, sense.

[0016] Figure 1 shows a block diagram of a system **10** according to one implementation of the invention. System **10** transmits data belonging to an outgoing channel over an ATM virtual connection **12** in a data link **13**. Data link **13** may, for example, comprise a fiber optic cable, an electrical cable, a wireless ATM link, or the like. The nature of the physical layer is not particularly important to this invention. One or more streams **14** of data are received at an interface **16** of system **10** for transmission over ATM virtual connection **12**.

[0017] System **10** comprises one or more additional interfaces **16** which are not shown in Figure 1. Each interface **16** handles data belonging to an outgoing channel. The data for each outgoing channel is passed on to some destination. The data for each outgoing channel may be destined for a certain connection, logical address, queue, path or the like. Multiple outgoing channels may have destinations on the same physical device. In Figure 1, data for the outgoing channel associated with interface **16** is carried toward its ultimate destination on ATM virtual connection **12**.

[0018] In the illustrated embodiment, an interface **16** of system **10** receives a plurality of data streams **14** each comprising a separate time domain multiplexing (TDM) channel in an incoming data link **15**. The source of data streams **14** is not particularly germane to this invention. Where multiple data streams **14** are received at system **10**, the data streams may be received over separate physical data links or may be multiplexed on a single data link, as shown.

[0019] In Figure 1 the illustrated interface **16** has only three incoming data streams **14**. In some implementations of the invention there may be many more incoming data streams **14**. For example, there

might be several hundred or even several thousand incoming data streams **14** by which data is received at interface **16**.

[0020] Interface **16** receives the one or more incoming data streams **14** and provides an adaptation function. In the illustrated embodiment, interface **16** provides for each incoming data stream **14** a processing function **18**, which may perform processing required by data of the data stream, and a packetization function **19**, which places the data of the data stream **14** into AAL2 packets **20**. AAL2 packets **20** are delivered to an outgoing cell assembler **22** which, in the illustrated embodiment also serves as a multiplexer. Outgoing cell assembler **22** places the AAL2 packets into ATM cells **24**. There is typically not a one-to-one correspondence between AAL2 packets and ATM cells **24**. Some AAL2 packets might fit entirely in one ATM cell **24** others might be split between two or more ATM cells **24**.

[0021] ATM cells **24** are carried on ATM virtual connection **12**. ATM virtual connection **12** is combined with other ATM virtual connections from other adaptation functions in ATM cell switch **20** for transmission over data link **13**.

[0022] When outgoing cell assembler **22** has a filled ATM cell **24** it sends the ATM cell **24** on ATM virtual connection **12**. Outgoing cell assembler **22** defers sending ATM cells **24** which are not filled. A CU timer system **30** causes outgoing cell assembler **22** to send ATM cells **24**, even if they are still only partially filled, before the data in the partially-filled ATM cells **24** is delayed excessively. When outgoing cell assembler **22** has a partially filled ATM cell **24**, it generates a partial cell available signal **32** which it sends to CU timer system **30**. CU timer system **30** is common to a plurality of interfaces **16**. Interfaces **16** may share common hardware elements.

[0023] As shown in Figure 2, CU timer system **30** comprises a timer **36** and an expiry time calculator **38**. In response to the receipt of a partial cell available signal **32** from outgoing cell assembler **22** expiry time calculator **38** establishes a time by which the cell being filled by outgoing cell assembler **22** should be transmitted, even if it is still not full. The time may be established, for example, by adding an amount to the current value of the time maintained by timer **36**. The amount may be, for example, a fixed amount or an amount specified by a value which may be independently configured for each interface **16** or each ATM virtual connection **12**. A data structure **40** is used to keep track of the expiry time(s) for any interfaces **16** from which a partial cell available signal **32** has been received.

[0024] Logic **42** identifies those partially filled ATM cells **24** referenced in data structure **40** which have an expiry time equal to the current time maintained by timer **36**. Logic **42** generates a send packet signal **33** to the appropriate outgoing cell assembler **22** which causes outgoing cell assembler **22** to forward its partially filled ATM cell **24** immediately for transmission on ATM virtual connection **12**. Outgoing cell assembler **24** may pad the unfilled portion of the payload of the ATM cell **24** with, for example, zeros.

[0025] System **10** preferably comprises a means for removing from data structure **40** references to ATM cells **24** which become filled after a partial cell available signal **32** has been generated but before their expiry times. In preferred embodiments of the invention, each of interfaces **16** is configured to generate a cell sent signal **34**. Cell sent signal **34** is generated when a partially filled ATM cell **24** becomes filled and can therefore be sent without delay. CU timer system **30** receives the cell sent signals **34**. Upon receipt of a cell sent signal **34**,

logic **44** in CU timer system **30** deletes reference to the cell from data structure **40**.

[0026] Data structure **40** preferably comprises a record which identifies each partially filled ATM cell **24** for which an expiry time has been set. The record preferably associates together the records of those partially filled ATM cells **24** whose expiry times are the same (or fall within the same window). Data structure **40** may comprise a series of lists, each list containing a record of all ATM virtual connections which comprise partially filled ATM cells **24** that are scheduled to expire at the same expiry time. Each list may be implemented, for example, as a linked list.

[0027] At each time increment, logic **42** retrieves from data structure **40** information identifying any ATM cells **24** which should be transmitted at that time increment. For each cell that is scheduled to be transmitted at that time increment, logic **42** generates and delivers to the appropriate outgoing cell assembler **22** a send now signal **33** indicating that the ATM cell **24** should be transmitted without further delay.

[0028] Typically, at any point in time, there will be a relatively small number of possible expiry times outstanding. For example, if the maximum CU timer range is 64 milliseconds (i.e. every packet should be transmitted, at worst, within 64 milliseconds) and the timer increment is 0.5 milliseconds then the number of potential expiry times is only 128. Therefore, only a relatively small number of expiry time lists need to be kept. Data structure **40** can therefore be conveniently held in a relatively small memory.

[0029] CU timer system **30** may be implemented, for example, in an application specific integrated circuit (ASIC) or in a field

programmable gate array (FPGA). CU timer system **30** may comprise a number of discrete memory components or regions, with one memory component or region set aside for each potential expiry time. In the alternative, CU timer system **30** could include one or more memories which each include lists of partially filled ATM cells **24**. One list is provided for each distinct expiry time or window. CU timer system **30** may include a single memory for holding all of data structure **40**.

[0030] Figures 3, 4 and 5 illustrate a specific embodiment of the invention. As shown in Figure 5, an interface **116** comprising control logic circuits receives packets **20** arising from one or more data streams **14** on an incoming data link **15**. Data in each of the data streams is destined for an outgoing channel carried by one of a plurality of ATM virtual connections **12**. Each data stream **14** may comprise a series of data packets. The data packets could, for example, comprise coded voice information, coded video information, segmented ethernet packets, segmented IP packets, or packets in some other format.

[0031] For each ATM connection (data for each outgoing channel is carried on a separate ATM connection in this example) a record **50** as shown in Figure 3 is maintained in a suitable memory **52**. Upon receiving a packet, interface **116** inspects the packet's header to determine which ATM virtual connection it should be forwarded to. Interface **116** then selects the instance of record **50** for that ATM virtual connection. Interface **116** may load the instance of record **50** into a working memory **127**.

[0032] In this embodiment of the invention, each record **50** includes several fields including the following:

- DATA - an area in which data from the data stream is assembled for inclusion in an ATM cell;

- FREE POINTER - a pointer to the next available space in the DATA area;
- NEXT CONNECTION IN LIST - this field may contain a pointer to a next record **50** for an ATM connection which has a partially filled cell having the same expiry time as the cell of the ATM connection corresponding to the current record **50**;
- PREVIOUS CONNECTION IN LIST - this field may contain a pointer to a previous record **50** for an ATM connection which has a partially filled cell having the same expiry time as the cell of the ATM connection corresponding to the current record **50**;
- MAX TIME - the maximum time which data for the corresponding ATM connection should be allowed to wait before being forwarded;
- OTHER STATUS INFORMATION - may contain various information specific to the implementation.

[0033] Upon receiving data destined for a particular ATM virtual connection **12**, interface **116** loads the appropriate record **50** into working memory **127** and then begins assembling the received data into the DATA area. In the illustrated embodiment the first byte of the DATA area is taken up with an AAL2 START FIELD which includes information about the ATM cell such as an OSF (offset), SN (sequence number) and P (parity) fields as defined in the I.363.2 standard. When the DATA area contains enough data to fill an ATM cell, interface **116** creates an ATM cell and places the completed ATM cell into an appropriate one of output queue(s) **56**.

[0034] When interface **116** has a partially filled ATM cell in the DATA area for the current record **50** and there is no more data immediately available to fill the ATM cell then interface **116** computes an expiry time for the partially filled cell by adding the value in the

MAX TIME field to the current value maintained by timer **126**. The resulting expiry time is used to store a reference to the current record **50** in CU timer memory **40**.

[0035] In the illustrated embodiment of the invention, CU timer memory **40** comprises a location corresponding to each possible upcoming expiry time. Each location in CU timer memory **40** can hold information identifying a record **50** corresponding to an ATM connection for which there is a partially filled cell having an expiry time corresponding to the location. The information may comprise, for example, a pointer to the location of the record **50** in memory **52**. Where the current record **50** corresponds to an ATM connection for which there is a partially filled packet, interface **116** writes information identifying the current record **50** to the location in CU timer memory **40** corresponding to the expiry time for the partially filled packet. If there is already another data stream referenced at that location in CU timer memory **40** (i.e. a previously processed ATM connection has a partially filled ATM cell which shares the same expiry time) then interface **116** copies the pointer to the record **50** of the previously processed connection to the NEXT CONNECTION IN LIST field of the current record **50**.

[0036] As this process is repeated for different connections, linked lists **130** (Figure 4) are built up. Each linked list contains references to those ATM connections which have partially filled ATM cells having the same expiry time. The head of each linked list is a location in CU timer memory **40** which corresponds to the expiry time.

[0037] For purposes of removing references to connections from the linked lists, each linked list is preferably a doubly-linked list. In the illustrated embodiment, when a location in CU timer memory **40**

includes a pointer to a previously inserted record **50** then interface **116** writes a pointer to the current record **50** in the PREVIOUS CONNECTION IN LIST field of the previously inserted record **50**. Figure 4, shows an example in which CU timer memory **40** is tracking 5 groups each containing one or more ATM connections which share the same expiry time. Each of these groups is represented by a doubly linked list **130**.

[0038] For example, location **140A** of CU timer memory **40** contains a pointer to the record **50C** for a connection "C". In memory structure **50C** the PREVIOUS CONNECTION IN LIST field contains a pointer to location **140A** of CU timer memory **40**, the NEXT CONNECTION IN LIST field contains a pointer to the record **50D** for a connection "D". In record **50D** the PREVIOUS CONNECTION IN LIST field contains a pointer to record **50C** and the NEXT CONNECTION IN LIST field contains a pointer to the record **50E** for a connection "E". In record **50E** the PREVIOUS CONNECTION IN LIST field contains a pointer to record **50D** and the NEXT CONNECTION IN LIST field contains a null pointer.

[0039] Memory **52** may contain records **50** for ATM connections which do not have partially filled packets. For example, Figure 4 shows records **50J**, **50K**, and **50L** which are not linked directly or indirectly to any location in CU timer memory **40**. In these records **50** both the PREVIOUS CONNECTION IN LIST field and the NEXT CONNECTION IN LIST field may contain null pointers.

[0040] During operation of interface **116**, timer **126** tracks the current time. A current time pointer (Fig. 4) identifies the location in CU timer memory **40** which corresponds to the current time. A timeout pointer (Fig. 5) may also be provided. The timeout pointer typically

points to the same location in CU timer memory **40** as the current time pointer. The timeout pointer points to the location in CU timer memory **40** to which any records **50** which are currently being processed are linked.

[0041] The current time pointer and timeout pointer move sequentially through the locations of CU timer memory **40**. It takes some time to process each record **50**. When a large number of connections have cells expiring at the same or closely spaced expiry times the timeout pointer may lag behind the current time pointer by one or more locations in CU timer memory **40**. Where there is sufficient processing capacity to process all connections which could expire at any particular expiry time before the next expiry time then a timeout pointer is not required.

[0042] When the timeout pointer moves to a location in CU timer memory **40**, interface **116** checks to see if that location holds a pointer to a record **50**. If not, there are no partially filled ATM cells which have expiry times which require them to be sent immediately. If there is a pointer to a record **50** then interface **116** retrieves the pointed-to record **50** from memory **52** and places the data in it into an ATM cell in an output queue **56**. Interface **116** continues to send unfilled ATM cells for all of the connections having records **50** identified in the linked list **130** having its head at the location in CU timer memory **40** which is pointed to by the timeout pointer. When this has been completed then a null pointer is inserted into the location in CU timer memory **40**. If the timeout pointer is not pointing to the same location in CU timer memory **40** as the current time pointer, and there are no records **50** pointed to by the location in CU timer memory **40** identified by the timeout pointer, then the timeout pointer moves to the next location in CU timer memory **40** and the steps described in this paragraph are repeated.

[0043] Sometimes a partially filled ATM cell will be filled by newly received data before its expiry time. If this occurs then it is desirable to send the cell immediately and to remove reference to the connection to which the cell belongs from the linked list corresponding to the cell's expiry time. Interface **116** can accomplish this by retrieving the record **50** for the data stream and identifying all pointers to that record **50** in the doubly linked list **130**. This can be done by identifying:

- from the PREVIOUS CONNECTION IN LIST field the location in CU timer memory **40** (or record **50**) which points to that record; and,
- from the NEXT CONNECTION IN LIST field any next record **50** in the doubly linked list **130**.

Interface **116** can then modify the doubly linked list by replacing the pointer to the current record **50** from the direction of the head of the list with a pointer to the next record **50** in the doubly linked list, if any (or with a null pointer if there is no next record **50** in the doubly linked list). If there is a next record **50** in the doubly linked list then interface **116** modifies the PREVIOUS CONNECTION IN LIST field for the next record **50** to be the same as the PREVIOUS CONNECTION IN LIST field for the current record **50**.

[0044] For example, if an unfilled ATM cell for CONNECTION D of Figure 4 became filled before the timeout pointer pointed to location **140A** then it would become necessary to remove record **50D** from the linked list **130** to which it belongs. This can be done by modifying record **50C** so that its NEXT CONNECTION IN LIST field points to record **50E** and modifying record **50E** so that its PREVIOUS CONNECTION IN LIST field points to record **50C**. The NEXT CONNECTION IN LIST field and PREVIOUS CONNECTION IN LIST field for record **50D** can then be set to null pointers.

[0045] The apparatus of Figure 5 may be implemented in an application specific integrated circuit ASIC or an FPGA. It is convenient to include working memory **127** and CU timer memory **40** in the ASIC or FPGA. Memory **52** may comprise an external memory, for example, an SRAM memory.

[0046] Figure 6 illustrates a method **200** according to the invention. Method **200** receives data for a plurality of data streams at an interface to a telecommunication link (block **210**). At block **212** the data is placed into cells for transmission across specific channels in the telecommunication link. Block **214** sends any filled cells across the corresponding channel in the telecommunication link (block **214** may comprise placing the filled cells into a queue or queues for transmission across the telecommunication link). Block **216** determines an expiry time for any partially filled cells.

[0047] In block **220** a record is made associating the connection over which the partially filled cell will be sent with the expiry time determined in block **216**. If the partially filled cell becomes filled before the expiry time then in block **224** the filled cell is sent and the record previously made in block **220** is deleted. Upon the expiry time being reached, the record made in block **220** is used to identify the connection with which the partially filled cell is associated together with any other connections having partially filled cells sharing the same expiry time (block **230**). Then the group of one or more partially filled cells which share the expiry time are sent on the appropriate connections (block **232**).

[0048] Those skilled in the art will appreciate that the application of this invention is not limited to sending AAL2 data packets over ATM

connections. The invention provides a general method for controlling the dispatch of data onto multiple connections in one or more telecommunication links where it is desirable that:

- the data should preferably be dispatched in packets or cells of at least a minimum preferred size; and,
- the data should be dispatched within a maximum time after it is received even if there is not enough data to fill a packet or cell to at least the minimum preferred size.

The packets or cells may comprise fixed-size cells, variable sized packets, or the like.

[0049] Figure 7 illustrates apparatus **300** according to one of many possible alternative embodiments of the invention. Apparatus **300** comprises a plurality of interfaces **316** which each receive data from one or more sources **14**. An interface **316** is provided for each of a plurality of outgoing channels. The way in which data **14** arrives at interfaces **316** and the format in which data **14** arrives at interfaces **316** is implementation-specific. At each interface **316** data is held in a buffer **317** in preparation for dispatching to a destination in the form of data packets **24'**. Data packets **24'** may comprise fixed-size cells, fixed size data frames, variable-size packets. Each interface **316** constitutes an outgoing packet assembler (which could also be termed an outgoing cell assembler in cases where packets **24'** comprise cells). A transmitter **320** retrieves from interfaces **316** and forwards data packets **24'** when they are ready for sending. A data packet **24'** is ready for sending when it either: contains more than a threshold amount of data; or contains data for which an expiry time has been reached.

[0050] When data arrives at an interface **316** it is placed into buffer **317**. If there is at least a threshold amount of data in buffer **317** then interface **316** causes a PACKET FULL signal **319** to be sent to

transmitter **320**. Transmitter **320** retrieves and transmits packets **24'** from the interface **316** as long as the PACKET FULL signal is asserted. When data which will start a new packet **24'** but will leave the new packet **24'** with less than a threshold amount of data arrives at interface **316** then interface **316** causes a PARTIAL PACKET ready signal **332** to be sent to CU timer system **330**. The PARTIAL PACKET READY signal may be sent, for example, when:

- buffer **317** is empty when the data arrives at interface **316** and the amount of data which arrives at the interface is less than the threshold amount;
- buffer **317** is empty when the data arrives at interface **316**, the amount of data which arrives at the interface is more than enough to completely fill one or more packets **24'**, and leave data left over in an amount less than the threshold amount;
- buffer **317** already contains some data and enough data arrives at interface **16** so that the combination of the data already present in buffer **317** and the newly-arrived data is more than enough to completely fill one or more packets **24'**, and leave data left over in an amount less than the threshold amount.

CU timer system **330** may function in substantially the same way as the CU timer system **30** shown in Figure 2.

[0051] Upon the expiry time for the data of any one of interfaces **316**, CU timer system delivers a SEND PACKET NOW signal **333** to transmitter **320**. The SEND PACKET NOW signal identifies the interface **316** for which the data should be sent (even though the threshold amount of data may not be available at that interface). Transmitter **320** then dispatches a packet **18** containing whatever data is present in buffer **317** of the interface **316**.

[0052] Where a packet is sent from an interface **316** before the expiry time of data in the packet then interface **316** causes a packet sent signal **334** to be delivered to CU timer system **330**.

[0053] Where a component (e.g. an assembly, device, memory, etc.) is referred herein, unless otherwise indicated, reference to that component (including a reference to a "means") should be interpreted as a reference to any component which performs the function of the described component (i.e. is functionally equivalent to the described component), including components which are not structurally equivalent to the disclosed structure which performs the function in the illustrated exemplary embodiments of the invention. Where a step in a method is referred to above, unless otherwise indicated, reference to that step should be interpreted as a reference to any step which achieves the same result as the step (i.e. is functionally equivalent to the described step), including steps which achieve a stated result in different ways from those disclosed in the illustrated exemplary embodiments of the invention.

[0054] As will be apparent to those skilled in the art in the light of the foregoing disclosure, many alterations and modifications are possible in the practice of this invention without departing from the spirit or scope thereof. For example:

- While the invention has been described as working to adapt AAL2 packets to ATM cells the invention could be applied in other situations where it is desirable to ensure that partially filled cells or packets are sent within a maximum time;
- While Figure 1 shows separate incoming and outgoing data links, incoming data link **15** and outgoing data link **13** could be carried on the same physical layer in certain implementations;

- The cells being sent are not necessarily ATM cells, the invention could be applied to sending other types of data cells or packets;
- The invention could be used to terminate placing data into a variable-length packet and to dispatch the packet at its current size if a maximum time period has elapsed since the first data was allocated to the packet;
- Where the invention is applied to the dispatch of variable-length packets the threshold amount of data may be either less than the maximum amount of data which can be carried by a packet or equal to the maximum amount of data which can be carried by a packet;
- While the invention has been illustrated as working with a plurality of data streams which are multiplexed into each outgoing channel the invention may also be applied in circumstances where there is only a single data stream for each outgoing channel;
- While the foregoing has described the application of expiry timers to connections, it is not necessary that there be any connections, either physical or virtual present. The invention could be applied to dispatching data over a network which is not connection-based. A CU timer system as described herein may be applied to any flow(s) of data destined for one or more common endpoints identified by destination addresses, paths which lead toward endpoints, or the like;
- While the embodiment of Figures 3, 4 and 5 uses records **50** associated with each connection both to keep track of information related to the status of the connection and to keep track of the associations of individual connections with specific expiry times, it would be possible to separate these functions;
- The invention could be implemented in software or hardware or a combination of software and hardware;

- The various functional components illustrated in the drawings may be combined with one another in different ways.

Accordingly, the scope of the invention is to be construed in accordance with the substance defined by the following claims.